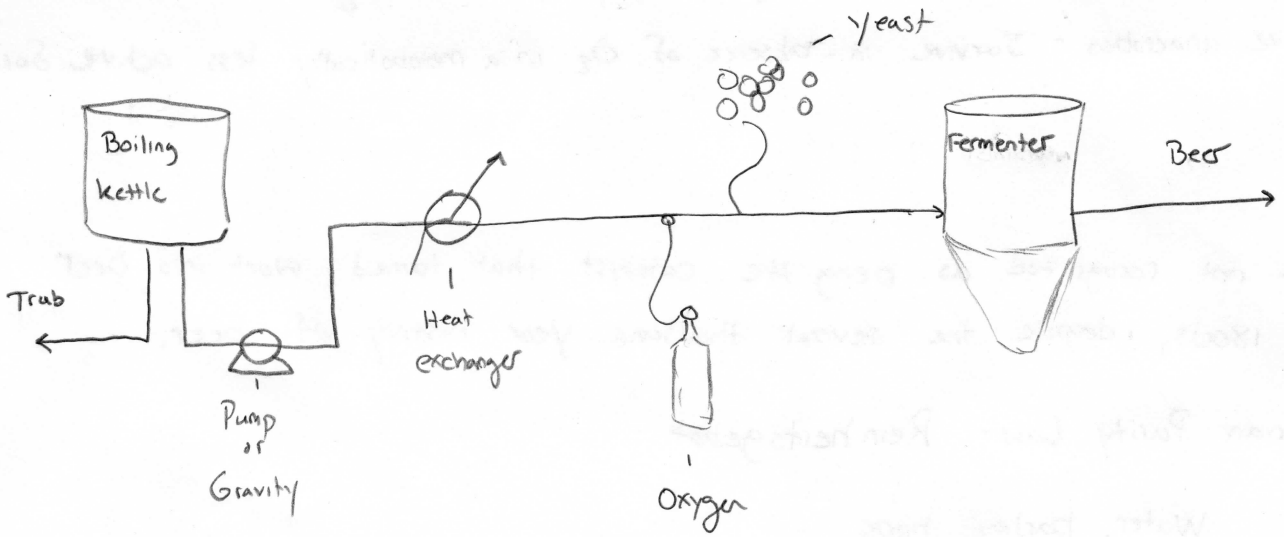
Fermentation

So far the entire brewing process, excluding malting, has required a full day or so of work. Care has been taken to produce a liquid wort full of simple sugars, hops and hop compounds, and other assorted finnings and free of any microbial life.



Priming the wort can be summarized

1) Hot wort is chilled to fermentation temperature → [8-11 °C → Lagers; 15-22 °C → Ales]
   ↳ passed through a heat exchanger

2) Cooled wort is oxygenated → 8-10 mg O_2 / liter wort
   ↳ cooler wort has higher gas solubility

3) Yeast is pitched
   ↳ either to fermenter or inline prior to entering fermenter

- Once in the fermenter, the most time consuming process begins.
- Fermentation can take anywhere from 7-21 days

→ 93-98 % of the total time

Yeast

- Fungi ⟶ genus: Saccharomyces
  - Saccharo - Sugar
  - Myces - Fungi
- Eukaryotic cells
- Heterotrophic - Require carbon source - sugar
  - Obligate aerobes - proliferate and grow in presence of O_2
  - Facultative anaerobes - Survive in absence of O_2 in a metabolically less active form

History

Yeast were not recognized as being the catalyst that turned wort into beer until the 1800s, despite the several thousand year history of beer.

Bavarian Purity Law - Reinheitsgebot

Water, barley, hops

1837 - Theodor Schwan - observed fungi in sterilized grape juice
⟶ Coined the term Sugar fungi

1855-1876 - Louis Pasteur - isolated different metabolic pathways (O_2 / Ferment)

Late 1800s - Harden and Young - $C_6H_{12}O_6 \rightarrow 2\,C_2H_5OH + 2\,CO_2$

3 Types of yeast

Ale yeast - top fermenting - 15 - 22°C (59 - 72°F)

Lager yeast - bottom fermenting - 8 - 11°C (46 - 52°F)

Weizen yeasts - Specialty wheat beers - 12 - 18°C (54 - 64°F)

Brewing Metrics

Pitching -

Ales - 0.40 - 1.00 million cells per ml per °P

lagers - 1.00 - 1.65 million cells per ml per °P

ex/

Ale — 12° P wort • $\frac{1.00 \text{ million cells}}{\text{ml} \cdot {}^\circ\text{P}}$ = $\frac{12 \text{ million cells}}{\text{ml wort}}$ - upper Range

too much yeast can result in:

- Faster Fermentation
- loss of bitterness -
- Reduced production of fermentation by products
- Reduced rate of proliferation - older yeast - autolyze

* Cell counts required to know how much of yeast pitch solution to add

- Common Assumption: $\frac{80 - 100 \text{ million cells}}{\text{ml}}$ - of Starter

ex/

100 Liters wort (12° P)

= 1,000,000 ml wort

$1{,}000{,}000 \text{ ml} \cdot \frac{12 \text{ million cells}}{\text{ml wort}} \cdot \frac{\text{ml Starter}}{80 \text{ million cells}} = 15{,}000 \text{ ml}$

or

15 liters

Attenuation - amount of extract that yeast have consumed

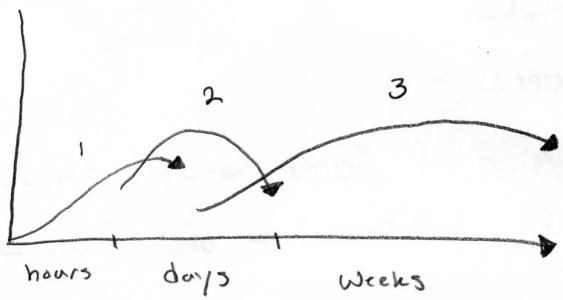
$$A = \frac{OG - FG}{(OG - 1)} \times 100$$

Different yeasts have different attenuations - tolerence of alcohol levels
- Complexity of sugars they can eat

Yeast Life cycle

The life cycle of yeast can be characterized by:

1) Adaptive phase
2) Aerobic phase
3) Fermentation

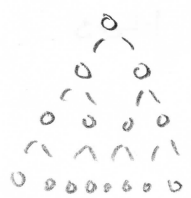


1) Adaptive phase - Uptake period

- Building materials (oxygen, simple sugars, lipids, amino acids) are absorbed
- Yeast is adapting to the environment
- Nutrients cue growth

2) Aerobic phase

- Aerobic respiration — Glycolysis, Citric Acid Cycle, Oxidative phosphorylation
- Energy supplied to proliferate — 2 ATP, 2 ATP, ~24 ATP
- Budding - yeast cells bud an outgrowth (Asexual)



at any point in time

50% - New (no scars) → Lipids to build membranes
25% - 1 scar
12.5% - 2 scars
6.25% - 3 scars
⋮ - n - scars

Doubling times ale - 3.5 x

lager - 2 x

10 million cells / ml wort	=	x 1	x 2	x 3	x 3.5
		20 million	40 million	80 million	120 million

3) Fermentation

- longest process, O_2 used up
  - → Ethanol and CO_2 production
  - → various side reactions
  - → Diacetyl consumption
- As attenuation limits are hit or once all sugars are consumed yeast begin to **Flocculate**
  - Flocculation is the clumping of yeast cells
    - low - yeast dont settle, makes filtering difficult
    - high - Good for clarity but diacetyl consumption is lowered

Metabolic products

Carbon Dioxide
Ethanol
} main

Higher aliphatic & aromatic alcohols - Aroma - 1-propanol | 2-methyl-1-Propanol
Esters - Taste (fruity notes) - Ethyl acetate
Carbonyl compounds - unripe taste - Aldehydes | ketones
Sulfur containing compounds - DMS - spoiling microbes
Organic Acids → pH drop to 4.3-4.6 - Acetic | formic acids
of Beer